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Analysing the distribution of SARS-CoV-2 infections in schools and shelters: integrating model predictions with real-world observations

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Abstract

The recent SARS-CoV-2 pandemic severely impacted lives around the world. In this study, we limit our focus to the school and homeless shelter communities. Widespread school closures were enacted in an attempt to mitigate transmission among the school populace, which adversely affected the academic performance of students, specifically those from a low socioeconomic background, as suggested by recent studies. Shelters house a highly vulnerable population that have access to limited housing and healthcare opportunities in the event of an outbreak. A deeper understanding of SARS-CoV-2 outbreaks would enable policymakers to respond to future pandemics through precision preventive measures in schools and shelters. The infection distribution encapsulates the statistics of outbreak spread, highlighting the key factors that drive transmission dynamics in these indoor locations. Though past works have studied such distributions from infection data, modeling them remain relatively unexplored.

In this study, our primary objective is to model the probability distribution of SARS-CoV-2 secondary infections from first principles, resulting in a distribution modeled exclusively from the underlying physics coupled with the biological parameters of the virus. The model accounts for both the long-range airborne transmission route arising from smaller aerosols airborne for extended periods, and the short-range route encompassing direct exposure to a wide range of aerosol sizes in proximity to the index case. Expected sources of transmission variability like viral load of the index case, dose-response, occupancy, indoor flow, virus-half life, etc., have been accounted for in model development.

To validate our model, available infection data from the Ontario public school system and Toronto shelters was collected and processed. Comparison of infection distributions from these datasets with modeled results display strong quantitative and qualitative match, demonstrating the model's capability at capturing the key mechanisms that underpin the transmission process. The results showcase the overdispersed nature of SARS-CoV-2 transmission arising from rare but high-impact superspreading events catalyzed by long-range transmission, along with frequent low-impact short-range transmission driven outbreaks. As the results are informed by the underlying governing parameters, effect of various mitigation measures on a large-scale system can be studied through appropriate modification of the model inputs, enabling the user to find optimal measures at combating future outbreaks.

This study puts forward a practical tool capable of predicting indoor airborne transmission statistics facilitating pandemic readiness for the future while providing insights into the fundamental mechanics governing the overdispersed nature of SARS-CoV-2 outbreak in schools and shelters.